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Pre-schoolers fundamental movement skills predict BMI, physical activity, and sedentary behavior: A longitudinal study

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Aims: This study aimed to predict the variation in future fundamental movement skills (FMS), physical activity (PA) and body mass index (BMI) from prior FMS, PA, and BMI in British pre-schoolers.

Methods: British pre-schoolers (n = 177) underwent assessment of FMS, via the Test of Gross Motor Development 2 (TGMD-2), BMI, and PA, via accelerometer at two time points one year apart. Regression analysis was used to predict the change in PA and BMI in Year 2 from FMS variables in Year 1 and Year 2.

Results: Variation in FMS performance between individuals predicted a significant amount of change in BMI, with 12.3 and 9.8% of the change in Year 2 BMI data explained by change in Year 1 and Year 2 FMS data, respectively. Change in FMS performance between individuals predicted a significant amount of change in PA, but was better at predicting change in sedentary activity rather than light or moderate-vigorous activities. A combination of run, throw, dribble, and kick performance predicted 46.1% of the change in sedentary activity between individuals in the 2nd year of testing.

Conclusions: FMS mastery at four years of age predicts children's BMI and time spent sedentary at five years of age.

KEYWORDS

early childhood, motor competence, sedentary behavior, weight status

1 | INTRODUCTION

Fundamental motor skills (FMS) are widely recognized as an important correlate of physical activity (PA), weight status, and a host of other psychological, social, and physical benefits.¹⁻⁴ Over the last decade, these important benefits of motor competence have led to an accelerating research interest in the topic of FMS development, specifically as it relates to lifelong health outcomes. It is understood that FMS

is a precursor to PA^{3,5-8} as learning to move is necessary for participation in PA. The development of FMS begins from birth, through the acquisition of locomotor, object manipulation and stability skills before becoming a central pillar of Early Years education.⁹ Understanding how FMS in early childhood shapes current and future levels of PA is therefore important because early childhood is a critical time to promote healthy behaviors.¹⁰ In particular, movement skills and activity behaviors during early childhood track to middle

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childhood and into adolescence.^{7,8,10,11} The importance of developing motor skills during early childhood have been identified as key behavioral determinant of PA habits by Condello and colleagues.¹² Using an umbrella systematic review approach Condello and colleagues¹² highlighted that, in the early years, motor skill development through youth sport clubs and school physical education provides a stimulus for the development of lifelong PA. As a consequence understanding how FMS are associated with PA and BMI over time in early childhood may be useful in promoting ways to improve lifelong PA.

Some studies have examined longitudinal relationships between previous and future FMS, and health outcomes such as PA and BMI in children.^{5,8,10,11,13,14} No longitudinal evidence has been forthcoming on associations between FMS and weight status in early childhood,³ and there are no studies examining this topic in British children. This latter point is important as recent research has identified that levels of FMS mastery are particularly low in British children.¹⁴ Duncan and colleagues¹⁵ reported that no British child aged 6-9 years of age in their sample had achieved mastery of four FMS (run, jump, throw, catch), identified as key outcomes by the UK curriculum, by the age the curriculum suggests they should. Non-UK-based research suggests that young children with higher FMS maintain positive patterns of PA over time⁸ and have higher levels of physical fitness over time.¹¹ Consequently, examining how FMS develop and might be associated with PA and weight status is important in British children below the age of 6 years. This approach could help identify opportunity for earlier intervention and more accurate targeting of resource for education professionals to promote positive trajectories of FMS in British children. This study sought to act on this gap by examining FMS, PA, and weight status, as assessed via BMI, in British pre-schoolers at two time points, one year apart. In this way, we aimed to predict the variation in future FMS, PA, and BMI from prior FMS, PA, and BMI. We hypothesized that current FMS would predict future FMS, PA, and BMI than current PA or BMI.

2 | METHODS

2.1 | Participants

This study used a short longitudinal design where children were assessed at two time points one year apart. Following institutional ethics approval, parental consent and child assent, a sample of 177 pre-schooler participants (age = 4.0 ± 0.74 years; 54% boys) were recruited at convenience from state-funded schools and pre-schools in the Coventry and Warwickshire areas, UK (Year 1). In the UK pre-school provision occurs in both pre-schools and schools,

where the latter have pre-school classes, hence why participants were recruited from both settings. Data collection took place during spring (March, April, May) and was repeated one year later (Year 2) and in the same month as initially tested. For Year 2, 91 participants (5.0 ± 0.70 years; 59% boys) agreed to participate and provided complete data, equivalent to 51% of the original sample. A priori power calculation for multiple linear regression analysis indicated that to detect a medium effect at $P = .05$ and 80% power a final sample size of 88 participants was required. The drop off was largely due to children ($n = 79$) leaving their pre-school setting and moving to primary schools out of geographical area or where the primary school ($n = 7$ participants) would not give permission for the research study to take place in their school.

3 | PROCEDURES

3.1 | Anthropometric measures

For both Year 1 and Year 2 trained researchers measured body mass (to the nearest 0.1 kg) and stature (to the nearest 0.1 cm) using digital scales (SECA 875) and a portable stadiometer (SECA 217), respectively. Body mass index (BMI) was calculated as kg/m^2 .

3.2 | Fundamental movement skills

Pre-school children were assessed on the TGMD-2 in their school facilities. FMS were assessed using the TGMD-2.¹⁶ Six locomotor (run, jump, hop, leap, gallop, and slide) and six object control (catch, throw, kick, bounce, strike, and roll) skills were assessed. Two trials of each skill were undertaken. Video recordings of each skill were taken in pre-school facilities (Sony Handicam CX405b, Sony, UK) and then used for later assessment and coding of the TGMD-2. Videos were edited into single-film clips of individual skills with Quintic Biomechanics analysis software v21 (Quintic Consultancy Ltd., UK). Scores from the two performance trials of each FMS assessment were summed to obtain a raw score for each skill. The combination of all FMS was then summed to create a total FMS score (scored 0-96). Scores from the run, jump, hop, leap, gallop, and slide were summed to create a locomotor (LC) skill score (0-48) and the catch, throw, kick, bounce, strike, and roll summed to create an object control (OC) skill score (0-48), following the recommended manual protocol for the administration of the TGMD-2.¹⁶ All scoring and coding was completed by one trained researcher and checked by a second researcher experienced in administration of the TGMD-2. Prior to data collection both raters had been trained by watching videos of pre-school children's skill performances (in two,

separate training sessions, lasting approx. 120min each) and comparing these against a previously rated “gold standard” criterion rating. Congruent with prior research,¹⁷ training was considered complete when each observer's scores for the two trials differed by no more than one unit from the criterion score for each skill (>80% agreement). Inter- and intra-rater reliability analysis between the two researchers were performed for all 12 motor skills. Intra-class correlation coefficients for inter- and intra-rater reliability (as absolute agreement) were 0.95 (95% CI = 0.87-0.95) and 0.93 (95% CI = 0.94-0.98), respectively, demonstrating good reliability.¹⁸

3.3 | Physical activity

Time spent in sedentary behavior, light PA and moderate to vigorous PA was determined using wrist worn triaxial accelerometry (GENEActiv Activeinsights, Cambridge, UK). Accelerometers were worn for five consecutive days with the first day removed to account for habituation and the remaining four days (2 weekdays, 2 weekend days) used for subsequent PA analysis. Accelerometers were worn on the child's dominant hand¹⁹ during all waking hours except for water-based activities to prevent skin irritation when drying. A sampling frequency of 100Hz was employed with data collected in 60s epochs. The accelerometer in question has demonstrated acceptable reliability and validity as a PA measure in children.^{19,20} Valid wear time was defined as a minimum of four consecutive days with two weekend days and at least 10 hours of data recorded between 6 AM and 10 PM. Non-wear time was defined as ≥ 20 -minute windows of consecutive zero or non-zero counts.²¹ PA was classified as sedentary (<8.1 g/s), light (8.2-9.3 g/s) or moderate and above (>9.3 g/s) in intensity using the Roscoe and colleagues²⁰ cut-points as these are the only validated cut-points for pre-school aged children.

3.4 | Statistical methods

All statistical analysis was performed using the Statistical Package for Social Sciences (SPSS, version 25). Regression relationships were determined between all measured variables and age (in months). Unstandardized age residuals were calculated, for any variables that were significantly ($P < .05$) related to age, to remove age as a confounding factor²²; Year 1 moderate and above physical activity, Year 1 FMS measures of leap, strike, dribble, catch, and kick, along with Year 2 FMS measures of jump, slide, skip, dribble, catch, and kick were all significantly related to age. Multiple linear regression analysis, with use of the enter method, was used to assess the multicollinearity of the FMS variables. Each individual FMS measure was checked for their variable inflation factor (VIF)

value. All FMS measures had a VIF < 2.6 which suggested that stepwise multiple linear regression analysis would be an appropriate method to analyze these data sets and that these sets of FMS skill scores can be seen as independent from each other when used to predict variation in measures of PA and BMI. In such cases assessing the contribution of each individual FMS rather than total FMS, or locomotor or object control subsets provides a more granular understanding of the contribution of FMS to PA and BMI. Multiple linear regression analysis, with use of the stepwise method, was used to assess whether variation between individuals in a potentially dependent variable (time spent in different intensities of PA or BMI) could be predicted from variation between individuals in FMS scores in Year 1 or Year 2. FMS scores from Year 2 were only used in attempts to predict measures of PA and BMI from Year 2. Data were analyzed as one group and for boys. The sample size was insufficient to analyze girls separately.

4 | RESULTS

In Year 1, of the 177 participants, 96 were boys and 81 were girls, mean \pm SD of age = 4.46 ± 0.75 years. This was compared to a sample of 91 participants in Year 2 comprising 54 boys and 37 girls, mean \pm SD of age = 5.42 ± 0.70 years. Mean \pm SD of BMI was 16.1 ± 1.7 kg/m² in Year 1 and 16.2 ± 2.4 kg/m² in Year 2.

4.1 | Combined boys and girls data

Variation in FMS performance between individuals explained a significant amount of variation in BMI (Table 1). There was little difference in the extent to which FMS Year 1 and Year 2 data could predict Year 2 BMI data. Year 1 FMS explained 12.3 of the variation in Year 2 BMI. This is compared to Year 2 FMS which explained 9.8% of the variation in Year 2 BMI (See Table 1).

Variation in FMS performance between individuals predicted a significant amount of variation in the amount of PA undertaken, but was better at predicting variation in sedentary activity rather than light or moderate-vigorous activities (Table 1). Forty-six percent of the variation in sedentary activity between individuals in the 2nd year of testing could be predicted by a combination of variation in run, throw, dribble and kick performance ($F_{4,33} = 8.92$, $P < .001$).

4.2 | Boys data

When boys data were analyzed separately, rather than combined with girls data, there was generally an improvement

TABLE 1 Multiple linear regression models, of combined data for boys and girls, which predicted variation in physical activity measures or body mass index from fundamental movement skills

	Year 1 FMS (n = 177)				Year 2 FMS (n = 91)			
	<i>F</i> value	<i>P</i> value	% of variation predicted	Predictors from Year 1 FMS	<i>F</i> value	<i>P</i> value	% of variation predicted	Predictors from Year 2 FMS
BMI Year 1	$_{1,71} = 4.60$ $_{2,70} = 4.91$	.035 .01	4.8 9.8	Jump Jump, slide	—	—	—	N/A
BMI Year 2	$_{1,71} = 5.40$ $_{2,70} = 6.03$	.023 .004	5.8 12.3	Jump Jump, slide	$_{1,88} = 6.80$ $_{2,87} = 5.86$	.011 .004	6.1 9.8	skip _{res} skip _{res} , run
Sedentary Year 1	$_{1,53} = 6.78$	.013	9.7	Catch _{res}	—	—	—	N/A
PA light Year 1	$_{1,53} = 7.84$	.007	11.2	Catch _{res}	—	—	—	N/A
PA moderate Year 1 _{res}	—	—	—	None	—	—	—	N/A
Sedentary Year 2	$_{1,32} = 8.91$	.005	19.3	Skip	$_{1,36} = 5.21$ $_{4,33} = 8.92$	.028 <.001	10.2 46.1	Run Run, throw, dribble _{res} & kick _{res}
PA light Year 2	$_{1,32} = 4.78$	.036	10.3	Skip	—	—	—	None
PA moderate Year 2	$_{1,32} = 5.25$	.029	11.4	Hop	—	—	—	None

Note: For sedentary Year 2 there was a total of 4 models produced using Year 2 FMS, but just the 1st and 4th model are shown.

Abbreviations: N/A, not applicable. Res, age independent residuals.

TABLE 2 Multiple linear regression models, of boys' data, which predicted variation in physical activity measures or body mass index from fundamental movement skills

	Year 1 FMS (n = 96)				Year 2 FMS (n = 54)			
	<i>F</i> value	<i>P</i> value	% of variation predicted	Predictors from Year 1 FMS	<i>F</i> value	<i>P</i> value	% of variation predicted	Predictors from Year 2 FMS
BMI Year 1	$_{1,43} = 5.60$	.023	9.5	Jump	—	—	—	N/A
BMI Year 2	$_{1,43} = 8.52$ $_{2,42} = 8.04$	.006 .001	14.6 24.2	jump jump, slide	$_{1,51} = 43.9$ $_{2,50} = 25.6$	<.001 <.001	42.5 48.6	Run run, kick _{res}
Sedentary Year 1	$_{1,33} = 6.76$	.014	14.5	Catch _{res}	—	—	—	N/A
PA light Year 1	$_{1,33} = 7.88$	.008	16.8	Catch _{res}	—	—	—	N/A
PA moderate Year 1 _{res}	—	—	—	None	—	—	—	N/A
Sedentary Year 2	$_{1,20} = 6.10$	.023	19.6	Skip	$_{1,22} = 5.18$ $_{3,20} = 9.06$	.033 .001	15.4 51.2	Run Run, dribble _{res} & kick _{res}
PA light Year 2	—	—	—	None	$_{1,22} = 8.92$	.007	25.6	Kick _{res}
PA moderate Year 2	—	—	—	None	—	—	—	None

Note: For sedentary Year 2 there was a total of 3 models produced using Year 2 FMS, but just the 1st and 3rd model are shown.

Abbreviations: N/A, not applicable. Res, age independent residuals.

in the amount of variation between individuals in BMI or PA that was predicted by variation in FMS (Tables 1 and 2). Variation in FMS performance between individuals predicted a significant amount of variation in BMI, however BMI in Year 2 was best predicted by FMS in Year 2 rather than FMS in Year 1 (Table 2). A combination of variation

in run and kick performance predicted 48.6% of the variation in BMI between individuals in the 2nd year of testing ($F_{2,50} = 25.6$, $P < .001$).

Variation in FMS performance between individuals predicted a significant amount of variation in the amount of PA undertaken, but was better at predicting variation in

sedentary activity rather than light or moderate-vigorous activities (Table 2). A combination of variation in run, dribble, and kick performance predicted 51.2% of the variation in sedentary activity between individuals in the 2nd year of testing ($F_{3,20} = 9.02$, $P = .001$).

5 | DISCUSSION

To date, there is no longitudinal data examining how FMS relates to PA and BMI in British pre-school children and there is a need for longitudinal studies, especially studies that include multiple variables (ie, those identified in the Stodden and colleagues⁶ conceptual model) in one sample. Therefore, the present data is useful to inform Physical Education practice in pre-schools. The key findings of the current study are that, in British pre-school children, better scores for the jump and the slide in Year 1 significantly predicted subsequent lower BMI in Year 2, such that just over 12% of the variation in Year 2 BMI could be predicted from variation in jump and slide performance in Year 1. Specifically, the novel aspect of the current study is the identification of those skills more predictive of PA. The findings of the current study add empirical support to the Stodden⁶ conceptual model in identifying a direct link between FMS in the early childhood years and BMI one year later. The Stodden⁶ conceptual model explains how FMS influences PA and subsequent weight status in childhood. The model suggests that, in pre-school aged children, a reciprocal relationship is evident where FMS has a direct effect on PA, but also that PA has a direct effect on development of FMS. Perceived motor competence and health-related fitness are suggested mediators of this model. Importantly, although both Year 1 and Year 2 FMS data significantly predicted Year 2 BMI, it was prior FMS (ie, Year 1), that was the stronger predictor of current (ie, Year 2) BMI. Such a finding is congruent with the assertions of the Stodden⁶ conceptual model that development of FMS will take time to have an impact on health-related outcomes such as BMI due to the cyclical relationship between PA and FMS. When considering which FMS contributed to the model, only variation in a few locomotor skills (jump and slide for Year 1, skip and run for the whole sample) helped explain variation in BMI values. Considering the age of the pre-school children in the current study, this may not be surprising. Locomotor skills are usually those first developed,²³ with object control skills being more difficult and taking longer to master.²⁴ It may be of course that there was not sufficient variation in some of the individual FMS skills to be predictive. For example, if no one can catch and this did not change from Year 1 to Year 2 it will not be particularly discriminative. One prior study conducted by Bryant and colleagues⁷ in older primary school children, likewise

reported that current FMS and FMS one year prior both significantly predicted children's current BMI. Prior work by Lopes and colleagues⁸ and Bryant and colleagues²² has similarly established an association between BMI and FMS in primary school children and authors suggest that inverse association between FMS mastery and BMI emerge at the pre-school age.²⁵ The results of the current study align with these prior studies and the assertions made by Bryant and colleagues,⁷ by using a similar approach to their work but focusing on pre-school children.

However, in the aforementioned work by Bryant and colleagues,⁷ prior FMS (one year before) significantly predicted current PA. In their study PA was assessed using pedometry, which although provides an objective assessment of PA, only provides an overall measure of total volume of PA undertaken. In the present study, a more encompassing insight into the impact of FMS on movement behavior can be provided as accelerometry was used to provide objective assessment of time spent in light PA, moderate to vigorous PA and sedentary behavior. The present study suggests that Year 1 FMS significantly predicted time spent in both light PA and moderate to vigorous PA one year later. In both cases, only locomotor skills contributed to the model where variation between individuals in skip and hop mastery contributed to the prediction of variation between individuals in light PA and moderate to vigorous PA, respectively. A recent Australian study in young children also used accelerometers and reported the reverse relationship, that is, that MVPA at 3.5 years was predictive of locomotor skill at 5 years.²⁶ Interestingly in this study, MVPA was not cross-sectionally associated with locomotor skill at age 5 years. Similar to our BMI findings, it is the prior behavior, (in this case MVPA) that is more important in determining the current behavior (in this case skill). Such a suggestion also underlines the findings of Condello and colleagues¹² umbrella systematic review which highlighted the relevance of behavioral determinants for PA in the early childhood years. This was particularly highlighted in the context of motor skills to provide holistic development of PA during childhood through organized sport, school physical education, free play, and time spent outdoors.¹²

The present study presents novel data showing that FMS may have a stronger influence on sedentary behavior than PA. Our data demonstrate that just over 19% of the variation between individuals in current time spent in sedentary behavior is predicted from variation in pre-school children's FMS one year previously, such that those with a higher skip score in Year 1 are likely to spend less time in sedentary activity in Year 2. To the authors knowledge no study to date has demonstrated this association. Forty six % of the variation in time spent in sedentary behavior in Year 2 was predicted from variation in a mix of locomotor (run) and object control (throw, dribble, kick) skills measured in Year 2, such that

those with higher performance in those FMS were likely to spend less time in sedentary behavior.

Other longitudinal studies in older children^{5,8} have similarly supported a linked developmental trajectory between FMS and PA, but in older children, it appears that object control skills may be more predictive.²⁷ Barnett and colleagues⁵ reported that variation in object control skill competence in childhood accounted for 3.6 and 18.2% of the variation in participation in moderate to vigorous PA and organized sport during adolescence, respectively. Lopes and colleagues⁸ also reported that when FMS was high in children aged six years of age they reported higher PA, via self-report, at the age of nine compared to children who had initial low or moderate levels of FMS. Unlike this prior work, the use of objective measures of PA in the current study strengthens the data presented and allows the distinction between time spent in moderate to vigorous physical activity, light PA, and sedentary behavior which has not been presented previously with longitudinal data in pre-school children.

The current study is not without limitations. The sample size and sex composition for data collected in Year 2 were not sufficient to allow us to complete regression analysis for girls data on its own, hence why we present data for the combined sample. Since gender differences do exist in motor skills, future research should seek to investigate longitudinal trajectories with sufficient power to be able to ascertain girls and boys trajectories separately.¹ There was a 51% retention participant rate at Year 2 with more boys providing consent to take part than girls. We are not sure why this is the case but it highlights the challenges of conducting longitudinal research with children of these ages. The main reason for the lack of retention is due to tracking children when they moved from pre-schools, where consent to take part had been initially granted by the head teacher, to primary schools where consent for the children to be involved was not forthcoming from head teachers or children moved to schools outside of the geographical catchment area of the study.

Although the use of accelerometers to objectively assess movement behaviors should be considered a strength of the current study, ensuring pre-school children wore the accelerometers over four days for a minimum of ten hours per day is logistically challenging. Accelerometers were also removed for water-based activity such as swimming. There is also the possibility that children or parents forgot to reattach accelerometers each morning or that some children found them uncomfortable and did not wear them. While parents were asked to feedback when accelerometers were removed during the monitoring period, instances of non-wear of the accelerometers was not always well reported. It may therefore be possible that PA was underestimated where pre-school children undertook swimming lessons/activity during the monitoring period. Similarly, for pre-school children in Early Years settings all sedentary behavior may not necessarily be considered equal. For example, some sedentary activities undertaken in Early Years settings would involve perfecting

other fine motor competence skills used for writing, or utensil manipulation, while others might relate to engagement in screen time. Yet accelerometers will only quantify the volume of sedentary behavior, not the type of behavior undertaken and there may be subtle differences in the benefits of sedentary behavior depending on what it actually is.

6 | PERSPECTIVE

The key take home message of this study is that pre-school children's BMI and time in sedentary behavior at the age of five years is predicted by FMS one year earlier (four years of age). Such information is needed to inform physical education practice and health policy in the UK and suggests a need to focus on developing FMS in pre-schoolers, with a particular emphasis on running, throwing, dribbling, and kicking, to benefit current and future health-related variables of BMI and physical activity.

CONFLICT OF INTEREST

None.

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